REMARKS

Applicants amend claims 1, 6, 13, 19, 21 and 23 and add new claim 25. Support for the amendments and the new claim is provided throughout the specification. Thus, no new matter is added. As discussed in detail below, application is in condition for allowance. Hence, reconsideration and allowance are respectfully requested.

Rejections Under 35 U.S.C. 112

In response to rejections of claims 8, it is amended to depend on claim 7, which recites an imager, rather than claim 6, thereby providing sufficient antecedent basis for recitation of the imager.

Further, claim 21 is amended to recite "a display," thereby eliminating the need for antecedent basis. Accordingly, the rejections of claim 21, as well as claim 22, which was rejected due to its dependence on claim 21, are overcome.

Rejections Under 35 U.S.C. 103

The Office Action rejects claims 1-16 and 23 as being obvious in view of the combined teachings of U.S. Patent No. Re 36,207 of Zimmerman and U.S. Patent No. 5,077,609 of Manelphe.

Broadly speaking, the present invention provides apparatus and methods for generating a perspective-corrected view of a portion of a wide-angle image. The claimed device employs a fish-eye lens to project a radially-distorted image onto an image plane. The device includes a processor with a first module that displays the distorted image, and a second module that displays a selected portion of the image in perspective-corrected form.

Importantly, and unlike prior art systems, the processor achieves perspective correction of the distorted portion from a *vantage point offset* from the center of a "hemispherical view" corresponding to the wide-angle image. This allows enhanced flexibility for viewing perspective-corrected views of the wide-angle image, even for viewing the full 180-degree field in perspective-corrected format.

Neither Zimmerman nor Manelphe teaches or suggests a processor that generates a perspective-corrected view of an image obtained by a fish-eye lens from a vantage point *offset* from the center of a hemisphere associated with the fish lens' field of view. More particularly, Zimmerman describes a device for multi-directional image viewing that provides pan-and-tilt, rotation, and magnification without utilizing any moving parts. The Zimmerman device includes a fish-eye lens that generates a distorted image of a hemispherical field of view, which is captured into an electronic buffer memory. A portion of the captured image corresponding to a region of interest is then transformed into a perspective-corrected image. This transformation is, however, accomplished by processing the distorted image based on an angle subtending the region of interest from a vantage point located at the *center* of the hemispherical field.

In contrast, the processor in the claimed device generates a perspective-corrected view of the distorted image from a vantage point *offset* from the center of a viewing hemisphere by a selected distance. The term "viewing hemisphere" is utilized herein as a short hand to refer to any wide-angle viewing field that has radial distortions in at least one dimension.

Hence, the image processing method of the invention is fundamentally distinct from that of Zimmerman, and results in significant advantages not provided by Zimmerman. In particular, Applicants explain that conventional methods for undistorting a portion of a fish-eye image, such as those described by Zimmerman, suffer from a number of shortcomings. For example, these methods can only be utilized for removing distortions from image portions corresponding to a small field of view, and will break down when applied to image portions corresponding to fields of view of tens of degrees, thus considerably diminishing the benefits of panoramic observation of a scene. *See*, e.g., specification, page 1, paragraph 4. For example, an "undistorted image obtained by utilizing such a conventional method exhibits progressively less resolution at points further away from the center of the image." In fact, "application of such conventional methods for undistorting even modest portions of a fish-eye image results in severe loss of resolution at points of the corrected image corresponding to edges of the undistorted image." *See* specification, page 18, paragraph 2.

In contrast, the transformation of a distorted fish-eye image from a vantage point offset from the center of the hemispherical field of view, as recited in claim 1, "affords enhanced flexibility for viewing portions of the fish-eye image throughout the full 180-degree field of view while compensating for distortions introduced by the fish-eye lens." For example, a comparison of FIGURE 9B with FIGURE 9C, presented in the specification, illustrates that the application of the methods of the invention to a distorted wide-angle image results in a perspective-corrected image that is "significantly enhanced in fidelity relative to an undistorted image obtained by employing conventional techniques." *See* specification, page 19.

The shortcomings of the Zimmerman are not bridged by Manelphe, which is directed to a wide-angle camera in which a wide-field image of scene is displayed on a first monitor and a small-field image corresponding to a section of the wide-field image is displayed on a second monitor. More specifically, unlike the claimed invention, Manelphe does not teach correcting a portion of the wide-angle image for perspective distortions from a vantage point offset from the center of a hemisphere corresponding to that image.

Hence, claim 1 distinguishes patentably over the combined teachings of the cited references. Further, claims 2-9 depend either directly or indirectly on amended claim 1, and hence are also patentable.

Claim 10, as amended, depends on claim 1, and further recites that the processor generates the perspective-corrected view by mapping a point (u,v) on an undistorted image plane corresponding to a perspective-corrected portion of a distorted image to a point (x,y) on a plane corresponding to the distorted image, where the mapping is provided by the following equations:

$$x = R\,(\beta_0 / (PI / 2))\cos(d_0)$$

$$y = R\,(\beta_0 / (PI / 2))\sin(d_0)$$

$$t = [D\,d + \mathrm{sqrt}(D^2\,d^2 - (u^2 + v^2 + d^2)\,(D^2 - 1))] / (u^2 + v^2 + d^2)$$

$$\beta_0 = \arctan(-D\cos(\beta) + d\,t\cos(\beta) - v\,t\sin(\beta), 1)$$

$$\delta_0 = \arctan(-D\sin(\beta) + d\,t\sin(\beta) + vt\cos(\beta), u\,t) + \delta$$

where β and δ are the zenith and azimuthal angles corresponding to the center of the undistorted image, β_0 and δ_0 are the zenith and azimuthal angles corresponding to a pixel (u,v) in the undistorted image, d is a magnification factor, D is a level of undistortion, and R is the radius of the fisheye image.

The equations presented in claim 10 are fundamentally distinct from those of Zimmerman in that these equations utilize an offset, namely, parameter D, relative to the center of hemispherical field of view that Zimmerman does not teach or suggest. As discussed in detail above, such an offset, though rendering the equations algebraically more complex, provides significant advantages. Hence, claim 10 is also patentable over the combination of the two cited patents. Moreover, claims 11 and 12 depend either directly or indirectly on claim 10, and are also patentable.

Independent claim 13, as amended, recites a device for providing a perspective-corrected view of at least a portion of a wide-angle image that includes an image-capturing device having a fish-eye lens for generating the wide-angle image, and a processor coupled to the image capturing device that receives the image. The processor displays the image and an associated graphical object for selecting a portion thereof. The processor responds to the selection of a portion of the image by generating a perspective-corrected view of that portion and replacing that image portion with the corrected view in the display of the image.

Zimmerman does not teach or suggest replacing a portion of a fish-eye image with its perspective-corrected version within a single display. Further, in Manelphe's device, a wide-field image is displayed on a first monitor and a small-field image corresponding to a selected portion of the wide-field image, possibly with a degree of enlargement, is displayed on a second monitor. That is, Manelphe does not replace the selected portion with an enlarged version of that portion within the original display, but rather displays the enlarged portion on a separate monitor.

In contrast, claim 13 recites that a selected portion of the distorted image is replaced with its perspective corrected version in the original display of the image. This provides a number of

advantages. For example, a "user can view at a glance not only a perspective-corrected portion of interest in the distorted image but also the relationship of this portion relative to the remainder of the distorted image."

Hence, claim 13, and claims 14 and 15 dependent on claim 13, distinguish patentably over the combined teachings of Zimmerman and Manelphe. Moreover, claim 16 that depends on claim 15 not only incorporates the patentable features of this claim, but it further recites additional patentable features. For example, it recites that the processor corrects the selected portion of the image for perspective distortions in accord with the selected magnification and angle for viewing a portion of a hemispherical field of view corresponding to the selected image portion from a vantage point *offset* from a center of the hemisphere. As discussed in detail above, utilizing a vantage point offset from the center of hemispherical field of view is not taught by Zimmerma. Nor does Manelphe teach such a feature. Hence claim 16 is also patentable over the cited references.

Independent claims 23 recites a device for imaging a field of view that includes an image-capturing device having a fish-eye lens for acquiring a fish-eye image of the field of view, a processor in communication with the image-capturing device, and a display coupled to the processor for presenting the fish-eye image and a perspective-corrected view of a portion thereof. The device further includes a graphical object presented on the display in association with a portion of the fish-eye image. The processor effects the presentation of the fish-eye image on the display, and further generates a perspective-corrected view of the portion of the fish-eye image associated with the graphical object. It also causes display of the perspective-corrected view within an area circumscribed by the graphical object. This allows not only viewing a perspective-corrected version of the selected area, but also discerning its juxtaposition relative to the other portions of the underlying fish-eye image.

Neither Zimmerman nor Manelphe presents a perspective-corrected view of a portion of a fish-eye image within an area circumscribed by a graphical object associated with the image on a single display. In fact, as discussed above, Manelphe utilizes a separate display for presenting a

perspective-corrected view of a portion of a wide-field image, and Zimmerman simply provides perspective-corrected view of regions of interest in a fish-eye image without simultaneously presenting the underlying image and the relationship of a corrected region relative to the other parts of the image.

Thus, claim 23 is patentable over the cited art.

Rejections Under 35 U.S.C. 102 And Further Rejections Under 103

The Office Action rejects claim 17 as being anticipated by Zimmerman.

Claim 17 recites a device for providing a perspective-corrected view of at least a portion of a wide angle image, which includes an image-capturing device having a fish-eye lens for generating the wide angle image, and a processor in communication with the image-capturing device. The processor corrects at least a portion of the image for distortions introduced by the fish-eye lens by mapping a point (u,v) of an undistorted image plane, corresponding to a perspective-corrected view of the image portion, to a point (x,y) of a distorted image plane, corresponding to the uncorrected image, in accord with an angle for viewing a section of the hemisphere corresponding to the image portion from a vantage point *offset from a center of the hemisphere* and a distance between the vantage point and the center of the hemisphere.

The arguments presented above apply with equal force to establish that claim 17 distinguishes patentably over Zimmerman. In particular, as discussed in detail above, Zimmerman does not teach a processor that corrects at least a portion of a fish-eye image from a vantage point *offset from a center of a hemisphere* corresponding to the fish-eye image and a distance between the vantage point and the hemisphere center. As also explained above, utilizing such an offset vantage point provides distinct advantages, e.g., it allows perspective correction of large portions, or even the entirety, of the fish-eye image without introducing artifacts.

In Paragraph 28, the Office Action rejects claims 18 and 24 as being obvious over Zimmerman.

As an initial matter, claim 18 depends on claim 17, and hence incorporates its patentable features. As discussed above, claim 17 distinguishes patentably over Zimmerman. Hence, similarly, claim 18 is patentable over this reference. Additionally, claim 18 recites that the processor employs the following equations to effect the mapping between the point (u,v) and the point (x,y):

$x = R\ (\beta_0 / (PI / 2))\ \cos(d_0)$

$y = R\ (\beta_0 / (PI / 2))\ \sin(d_0)$

$t = [D\ d + \text{sqrt}(D^2\ d^2 - (u^2 + v^2 + d^2)\ (D^2 - 1))] / (u^2 + v^2 + d^2)$

$\beta_0 = \arctan(-D\ \cos(\beta) + d\ t\ \cos(\beta) - v\ t\ \sin(\beta),\ 1)$

$\delta_0 = \arctan(-D\ \sin(\beta) + d\ t\ \sin(\beta) + vt\ \cos(\beta),\ u\ t) + \delta$

where β and δ are the zenith and azimuthal angles corresponding to the center of the undistorted image, β_0 and δ_0 are the zenith and azimuthal angles corresponding to a pixel (u,v) in the undistorted image, d is the magnification factor, D is the level of undistortion, and R is the radius of the fisheye image.

As discussed above, these equations are distinct from those disclosed by Zimmerman in that they include an offset factor, i.e., the parameter D, that Zimmerman does not teach or suggest.

Claim 24 recites a method for generating a perspective-corrected view of a portion of a fish-eye image by mapping a point (u,v) on an undistorted image plane corresponding to a perspective view of the image portion to a point (x,y) on a distorted image plane corresponding to the fish-eye image according to the following equations:

$x = R\ (\beta_0 / (PI / 2))\ \cos(d_0)$

$y = R\ (\beta_0 / (PI / 2))\ \sin(d_0)$

$t = [D\ d + \text{sqrt}(D^2\ d^2 - (u^2 + v^2 + d^2)\ (D^2 - 1))] / (u^2 + v^2 + d^2)$

$\beta_0 = \arctan(-D\ \cos(\beta) + d\ t\ \cos(\beta) - v\ t\ \sin(\beta),\ 1)$

$\delta_0 = \arctan(-D \sin(\beta) + d\ t \sin(\beta) + vt \cos(\beta), u\ t) + \delta$

where β and δ are the zenith and azimuthal angles corresponding to the center of the undistorted image, β_0 and δ_0 are the zenith and azimuthal angles corresponding to a pixel (u,v) in the undistorted image, d is the magnification factor, D is the level of undistortion, and R is the radius of the fisheye image

The arguments presented above with respect to claim 18 apply to establish that claim 24 is patentable, as well. In particular, Zimmerman fails to teach or suggest a material feature of the equations recited in this claim, namely, an offset D that corresponds to level of undistortion.

In Paragraph 31, the Office Action rejects claims 19 and 20 as being obvious over Zimmerman in view of U.S. Patent No. 5,489,940 of Richardson.

Independent claim 19 recites a device for imaging a field of view, which includes an image-capturing device having a fish-eye lens for generating a wide angle image of the field of view, and a processor coupled to the image-capturing device to receive the image. The processor can cause display of the wide-angle image and can further select a portion of the image based on a pre-programmed set of rules. Upon such selection, the processor generates a perspective-corrected view of the selected portion from a *vantage point offset from the center of a viewing hemisphere* and displays it.

As discussed above, Zimmerman does not teach generating a perspective-corrected view of a portion of a fish-eye lens from a vantage point offset from the center of a viewing hemisphere. Nor does it teach selecting a portion of a fish-eye image for perspective correction based on a pre-programmed selection rule. Moroever, Richardson does not bridge the shortcomings of Zimmerman to render the claimed invention obvious. Richardson is directed to an electronic imaging system in which a wide-angle lens projects an image of a scene onto a two-dimensional array of non-linearly distributed imaging elements. The non-linear distribution is designed to correct distortions introduced by the wide-angle lens. Thus, Richardson does not correct a distorted fish-eye lens image by applying a corrective procedure to data corresponding

to a distorted image, let alone the procedure described in the claimed invention. Rather, it relies on hardware, i.e., non-linear design of imaging elements, for perspective correction.

Thus, claim 19, and claim 20 that depends on claim 19, distinguish over the combined teachings of Zimmerman and Richardson.

In Paragraph 34, the Office Action rejects claims 21 and 22 as being obvious over Zimmerman in view of Richardson.

The arguments presented above in connection with claim 19 apply with equal force to establish that, similar to claim 19 on which these claims indirectly depend, they are also patentable over combined Zimmerman and Richardson.

New Claim

New claim 25 recites an imaging device that includes an image-capturing device having a wide-angle lens for generating an image of at least a portion of a viewing field associated with the lens, and a processor coupled to said image-capturing device for generating perspective correction of at least a portion of said image from a vantage point offset from a center of the viewing field.

As discussed in detail above, none of the cited art teaches or suggests an imaging device in which a processor corrects a portion of a wide-angle image from a vantage point offset from the center of the viewing field. Hence, new claim 25 is patentable over the cited art.

CONCLUSION

In view of the above amendments and remarks, Applicants respectfully request reconsideration and allowance of the application. Applicant invites the Examiner to call the undersigned at (617) 439-2514 if there are any remaining questions.

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Respectfully submitted,

By _____

Reza Mollaaghababa
Registration No.: 43,810
NUTTER MCCLENNEN & FISH LLP
World Trade Center West
155 Seaport Boulevard
Boston, Massachusetts 02210-2604
(617) 439-2000
(617) 310-9000 (Fax)
Attorney for Applicant

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